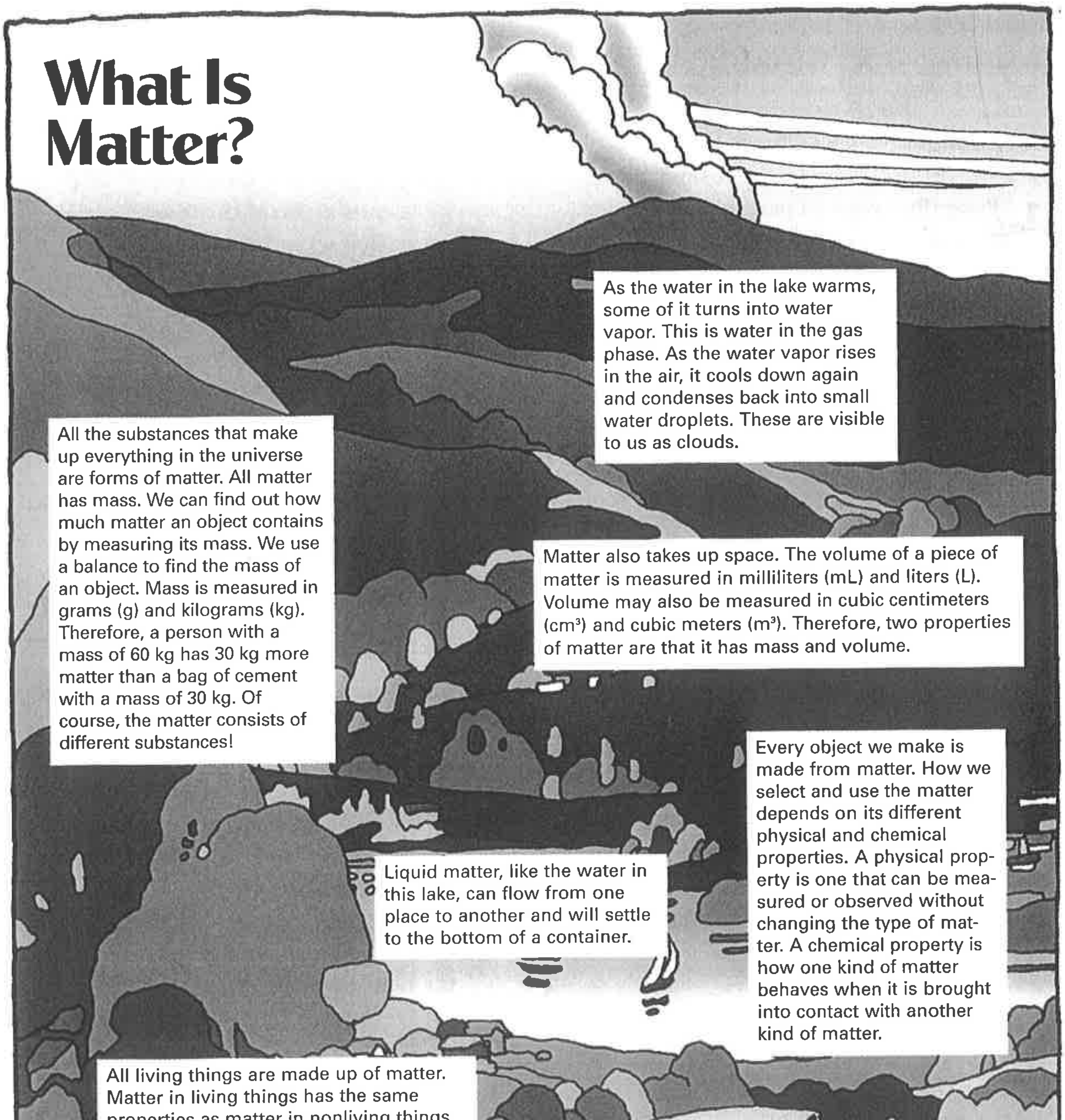
What Is Matter?



All the substances that make up everything in the universe are forms of matter. All matter has mass. We can find out how much matter an object contains by measuring its mass. We use a balance to find the mass of an object. Mass is measured in grams (g) and kilograms (kg). Therefore, a person with a mass of 60 kg has 30 kg more matter than a bag of cement with a mass of 30 kg. Of course, the matter consists of different substances!

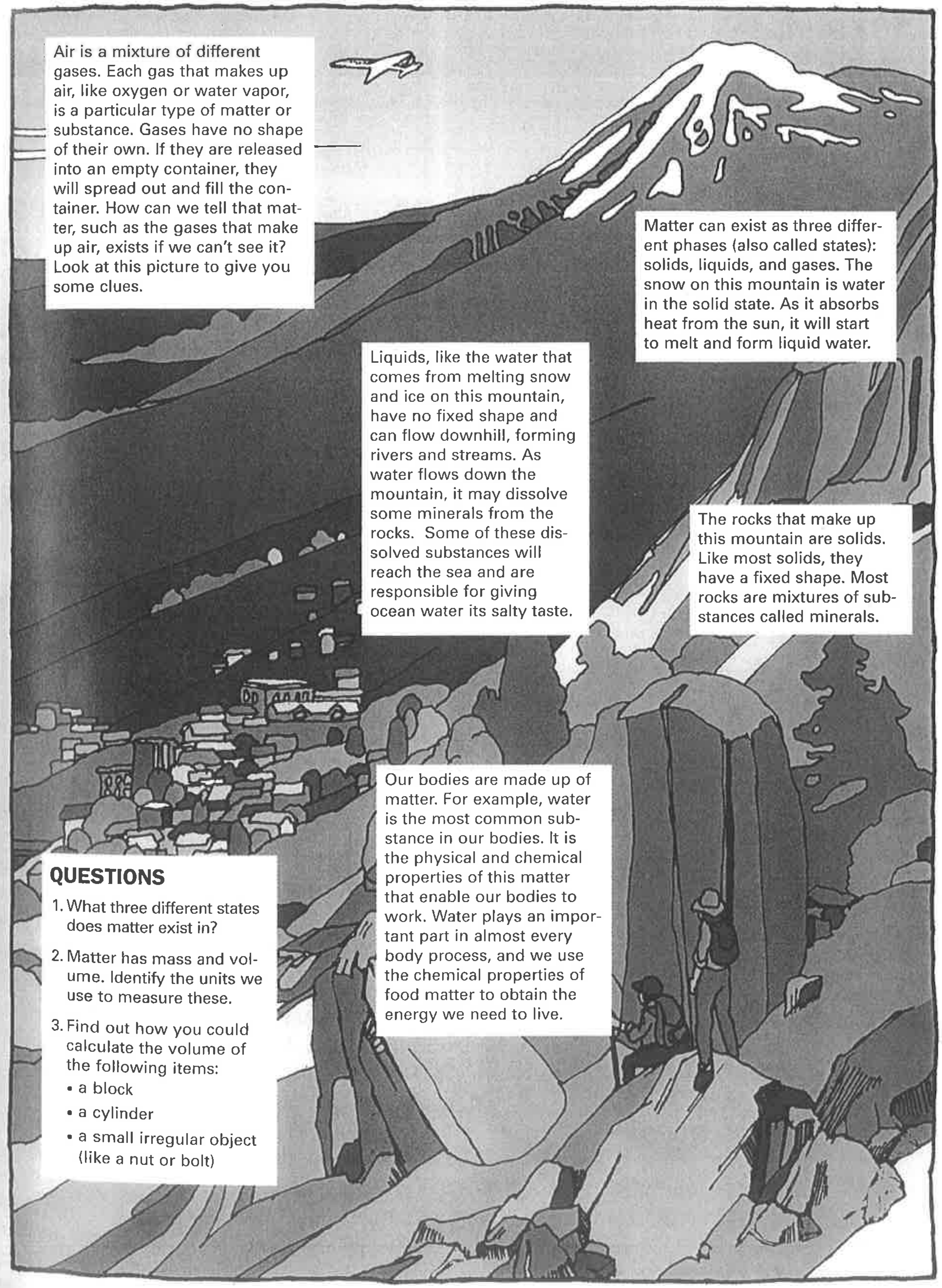
As the water in the lake warms, some of it turns into water vapor. This is water in the gas phase. As the water vapor rises in the air, it cools down again and condenses back into small water droplets. These are visible to us as clouds.

Matter also takes up space. The volume of a piece of matter is measured in milliliters (mL) and liters (L). Volume may also be measured in cubic centimeters (cm^3) and cubic meters (m^3). Therefore, two properties of matter are that it has mass and volume.

Every object we make is made from matter. How we select and use the matter depends on its different physical and chemical properties. A physical property is one that can be measured or observed without changing the type of matter. A chemical property is how one kind of matter behaves when it is brought into contact with another kind of matter.

Liquid matter, like the water in this lake, can flow from one place to another and will settle to the bottom of a container.

All living things are made up of matter. Matter in living things has the same properties as matter in nonliving things.



QUESTIONS

1. What three different states does matter exist in?
2. Matter has mass and volume. Identify the units we use to measure these.
3. Find out how you could calculate the volume of the following items:
   - a block
   - a cylinder
   - a small irregular object (like a nut or bolt)

WHERE DID MATTER COME FROM?

CORBIS/PENNY TWEEDIE

These Australian Aborigines are painting images of their Dreamtime story.

Where did all the stuff in the universe—Earth, the sun, rocks, plants, animals, even you—come from? Was it made at a certain time? If so, how long has it been around? Has it always been there? People have asked these questions since the earliest times.

Most cultures have stories of how the universe was created. For instance, Australian Aborigines tell a story about the sun, moon, and stars sleeping beneath the ground. Their ancestors also slept there. One day the ancestors woke up and came to the surface. The Aborigines call this the Dreamtime. During the Dreamtime, the ancestors walked the Earth as animals such as kangaroos, lizards, and wombats. Out of beings that were half animal and half plant, the ancestors made people. They then went back to sleep. Some went underground, but some became objects such as trees and rocks. The Dreamtime is an important part of Australian Aboriginal culture.

Scientists have also tried to answer the question of how the universe began. When scientists try to answer questions, they sometimes make observations of what happens and

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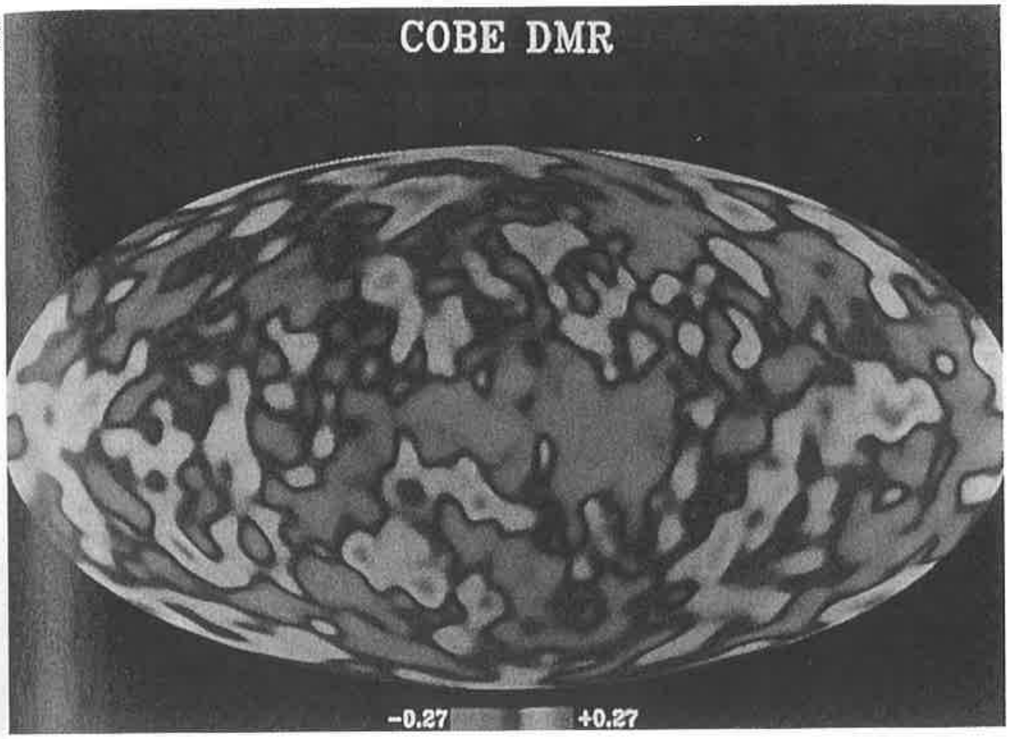

This background radiation map of the universe was produced using data collected by COBE (see photo below). The purple spots represent energy at the farthest edges of the expanding universe, giving a "picture" of the universe about 1 million years after the Big Bang. This image shows that even then, "structures" were being formed.

collect data. Scientists use their observations and data to try to explain the phenomena they are studying. One important part of science is the ability for different scientists to make the same observations and collect the same data when they are studying the same phenomena. When many scientists have made the same observations over a period of time, their explanations of these observations are called theories. As new knowledge is gained, theories are tested and retested. Sometimes the theories don't stand up to the new information. These theories are then replaced with new theories.

Over the years, as scientists have gained new knowledge about the universe, new theories have replaced old theories. Currently, many scientists think the universe started with the "Big Bang." The Big Bang theory suggests that all the matter and energy in the universe exploded out from one point. As the explosion occurred, energy and matter spread outward and formed the universe. The

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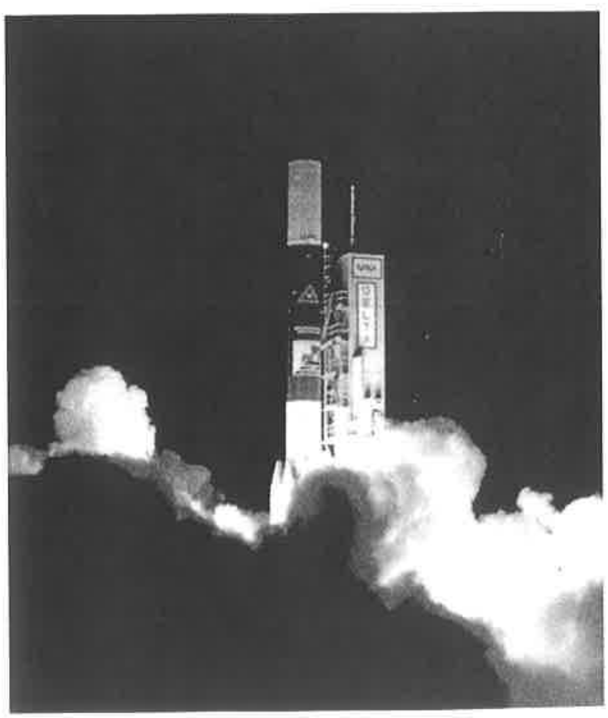
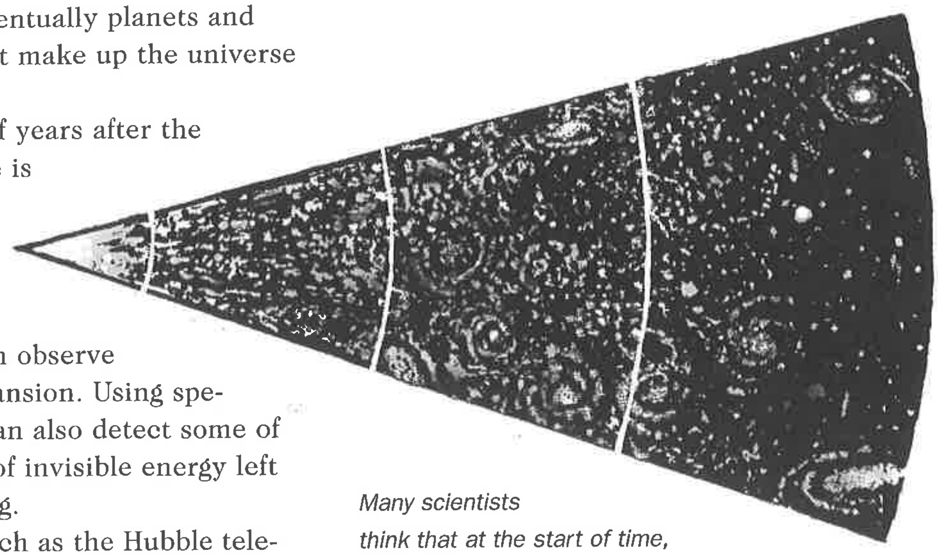


The Cosmic Background Explorer (COBE) satellite was launched in 1989. Its mission: Find out more about the origins of the universe by looking for background radiation left over from the Big Bang.

matter from the Big Bang formed clouds of gas. As these gases cooled and condensed, stars, galaxies, and eventually planets and other "structures" that make up the universe were formed.

Even now, billions of years after the Big Bang, the universe is still spreading out. By looking at light from distant stars and galaxies, scientists can observe and measure this expansion. Using special apparatus, they can also detect some of the background glow of invisible energy left over from the Big Bang.

Space telescopes, such as the Hubble telescope and X-ray telescopes in orbit around Earth, are constantly making new and exciting observations. Ideas about the formation of the universe and the Big Bang may change as these instruments are used to discover more about our evolving universe. □



Many scientists think that at the start of time, all matter and energy were contained within a single point. The point exploded in the Big Bang. The energy of this explosion caused the matter to spread out in all directions, forming galaxies, planets, and other objects. Using specialized instruments, scientists are able to measure the expansion of the universe.

USEFUL CALCULATIONS

Volume is a measure of space taken up by some matter. In this module, the units cubic centimeters or milliliters are used when measuring volume. Because 1 milliliter equals 1 cubic centimeter, these units are interchangeable.

The volume that something takes up can be measured in several different ways. A graduated cylinder can be used to measure the volume of liquids. The exterior dimensions of regular solid objects can be measured to calculate their volume. For example, the volume (measured in cubic centimeters) of a block can be calculated by measuring the block's length (l), height (h), and width (w) in centimeters and then multiplying these together, as shown in the following equation:

Volume of a block =
l (centimeter) × h (centimeter) ×
w (centimeter) = volume in cubic centimeters

Different formulas can be used to calculate the volume of other regular objects (such as cylinders or spheres). Volumes of solids can also be measured indirectly by using a graduated cylinder. This method is done by the displacement of water. You used this method in Inquiry 1.2.

Mass is a measure of the amount of matter in an object. In this module, gram is used as the unit for measuring mass. Mass can be measured using a balance.

The density of a substance is the mass of a known volume of a substance. It is usually measured in grams per cubic centimeter.

Inquiry 2.1 Measuring the Mass and Volume of Water

PROCEDURE

1. Collect the plastic box of materials for your group. Check its contents against the materials list. During this lesson, you will also use an electronic balance. Other groups will be sharing the balance with you. Your teacher will assign an electronic balance to your group.

2. Work with your partner. Take one of the graduated cylinders out of the plastic box. Examine it carefully. Discuss the answers to the following questions with your partner:

   A. What is the unit of measure for the graduated cylinder?

   B. What is the maximum volume it can measure?

   C. What is the minimum volume it can measure?

   D. What is the number of units measured by the smallest division on its scale?

3. In this experiment, you will investigate the mass of different volumes of a substance. The substance you will use is water. Discuss with your partner how you could find the mass of 50 mL of water by using the graduated cylinder and the electronic balance. Consider the measurements and the calculations you need to make. Write your ideas in your notebook. You will be expected to contribute your ideas to a short class discussion.

4. Record the steps of the agreed-upon class procedure on Student Sheet 2.1.

REFLECTING ON WHAT YOU'VE DONE

1. During the lesson, you measured the mass and volume and calculated the density of a liquid and some solids. All the substances had different densities. Your teacher will lead a discussion about the results from all three inquiries. To help you participate in the discussion, write your answers to the following questions in your notebook:

A. What is the difference between mass and volume?

B. What units did you use to measure mass and volume?

C. How did you calculate the density of an object?

D. What units did you use to measure density?

E. Does changing the amount of a substance change its density?

F. If two objects are made from the same substance, will they have the same density?

2. Read "Density as a Characteristic Property."

DENSITY AS A CHARACTERISTIC PROPERTY

The density of a substance is a characteristic of that substance. Therefore, density is a property that can be used to help identify a substance. Properties used to help identify substances are called characteristic properties.

Characteristic properties are not affected by the amount or shape of a substance: A bolt made from iron will have the same characteristic properties as the hull of an iron ship or a piece of iron railing. You will encounter more characteristic properties later in the module. Perhaps you can think of some now.

Knowing the density of a substance can be useful. For example, substances with low densities can be used to make objects that fly. Based on the results you obtained in Lesson 2, do you think steel or aluminum would be better for building an airplane? Would you want to make a bike out of lead? Why or why not?

Mass or Weight?

How much does this bag of sugar weigh?

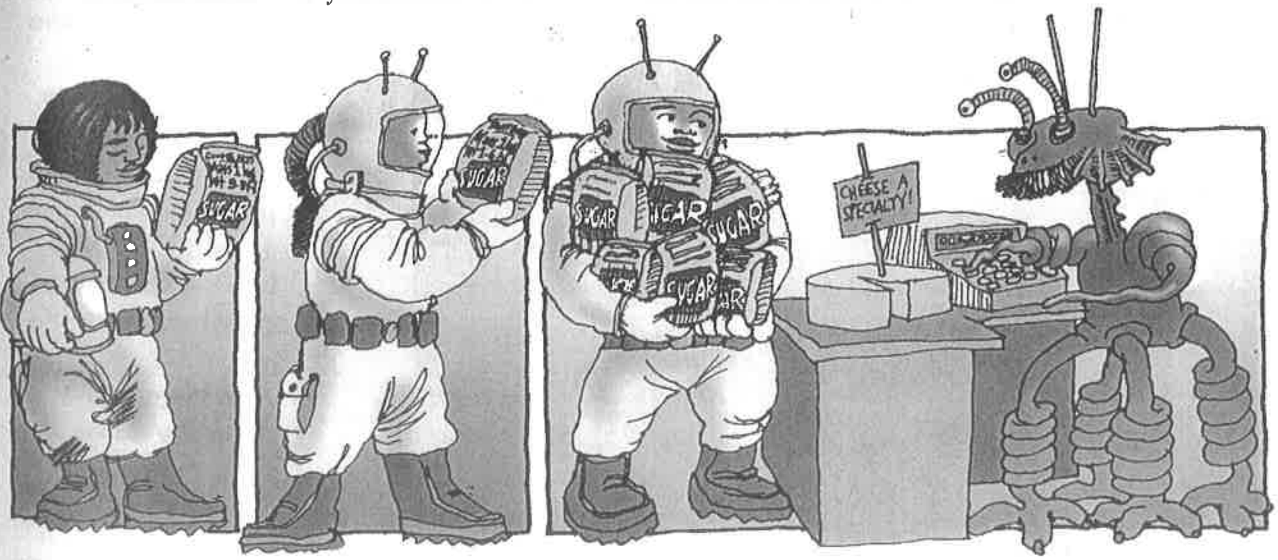
What is the weight of the sugar inside the bag in the picture? If you answer the question by saying 1 kilogram, you would be wrong! You see, kilograms and grams are units of mass, not weight. Weight is measured in units called newtons. Confused by the difference between mass and weight? Why do we need different units?

We have already discussed that mass is a measure of the amount of matter in an object. The bag contains sugar with a mass of 1 kilogram. Weight is quite different from mass. It is a measure of the force of gravity. Gravity is the force of attraction between two objects. Earth and the sugar are attracted to each other. This attraction varies with the size of the two objects and their distance apart. The force of attraction between a mass of 1 kilogram and Earth is about 9.8 newtons. So the answer to the question "How much does the sugar in this bag weigh?" is 9.8 newtons.

If an astronaut took the bag of sugar to the moon, what would be its mass? Would it contain the same amount of matter? The answer is yes. Provided the astronaut hasn't eaten or dropped any of the sugar, the bag would still contain sugar with a mass of 1 kilogram. What is the weight of the bag of sugar on the moon? The moon is much smaller than Earth, so the force of attraction between the sugar and the moon is less. Gravity on the moon is about one-sixth of that on Earth. So what is the weight of sugar on the moon? Divide 9.8 newtons by 6 and you'll get an approximate answer. ☐

QUESTION

How would the weight of the same bag of sugar on Mars and Jupiter differ from that on Earth? Explain your answer.



When it comes to mass, it doesn't matter where you are because the mass of an object is always the same. But if you are buying something by weight, you will get a lot more for the same cost if you buy it on the moon!

Archimedes' Crowning Moment

Archimedes, one of the most famous mathematicians and scientists of ancient Greece, had a problem. The king had a new crown. It looked like pure gold. But the king was suspicious. How could he be sure that the jeweler hadn't cheated him by adding another, less valuable metal to the molten gold? The king asked Archimedes to find out whether the crown was made from pure gold.

Archimedes knew his reputation was on the line. He could have taken the problem down to the public marketplace, where he often went to discuss scientific questions with other scholars. But instead, he decided to relax in a bath. The tub was filled to the brim. Still concentrating on his problem, Archimedes immersed himself in the water.

COURTESY OF THE SMITHSONIAN INSTITUTION, NEG. #56119

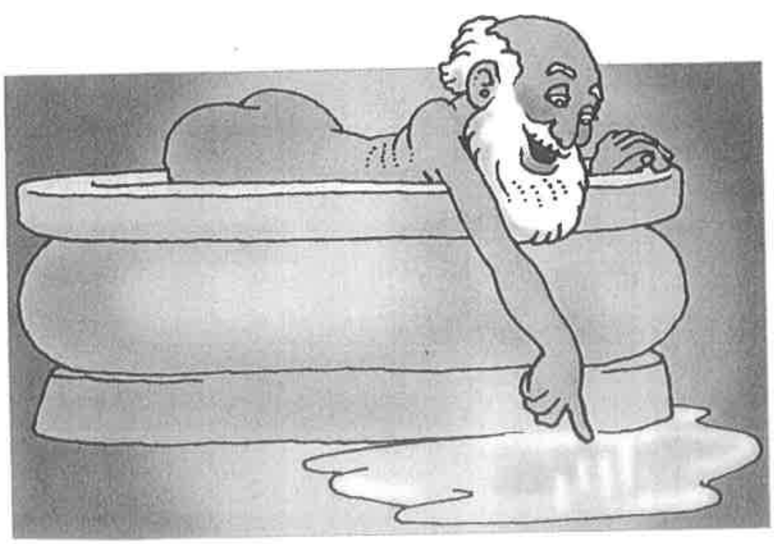
Archimedes was an expert on mass, volume, and density.

Splash! Water spilled over the sides of the tub and onto the floor. He had made a real mess. But that mess triggered an idea—an idea that would help solve the king's dilemma.

"When I got into the tub," Archimedes reasoned, "my body displaced a lot of water. Now, there must be a relationship between my volume and the volume of water that my body displaced—because if I weren't so big, less water would have spilled on my floor."

This observation brought Archimedes back to the problem of the gold crown. What if he put it in water? How much water would it displace? And could he apply this observation to prove that the crown was made of pure gold?

Archimedes knew about the importance of controls, so he began by finding a piece of gold and a piece of silver with



"Hmmm . . . the volume of my body equals the volume of water on the bathroom floor."

exactly the same mass. He dropped the gold into a bowl filled to the brim with water and measured the volume of water that spilled out. Then he did the same thing with the piece of silver.

Although both metals had the same mass, the silver had a larger volume; therefore, it displaced more water than did the gold. That's because the silver was less dense than gold.

Now it was time to check out the crown. Archimedes found a piece of pure gold that had the same mass as the crown. He placed the pure gold chunk and the crown in water, one at a time.

The crown displaced more water than the piece of gold. Therefore, its density was less than pure gold. The king had been cheated! Although this was just one of Archimedes' many contributions to science, there's no doubt that it was his "crowning moment"! □

QUESTION

Pretend you are Archimedes. What instructions would you give for comparing the density of a crown with the density of gold?

Why Did the *Titanic* Float?

On April 10, 1912, the luxury liner *Titanic* left England for New York and sailed straight into the annals of history. Why is the name *Titanic* so well known? At that time, she was considered the safest ship ever built; some people even considered her unsinkable. The *Titanic* became famous when she struck an iceberg and sank on her first voyage. About 1500 people drowned or froze to death in the ice-cold Atlantic water.

People often ask, "Why did the *Titanic* sink?" Perhaps a better question would be, "Why did the ship float?" She was, after all, made mainly from iron and steel. Her anchors alone weighed 28 metric tons. (That's almost 62,000 pounds!) Steel has a density about eight times that of water, so you would expect a ship made of steel to sink.

However, if you were to look at a plan of the *Titanic*, you would discover that most of her volume was occupied by air. Air has a density of about one-thousandth that of water. Therefore, the average density of the ship was less than the density of water. That's why she floated.

"All the News That's Fit to Print."

The New York Times.

TITANIC SINKS FOUR HOURS AFTER HITTING ICEBERG; 866 RESCUED BY CARPATHIA, PROBABLY 1250 PERISH; ISMAY SAFE, MRS. ASTOR MAYBE, NOTED NAMES MISSING

The Lost Titanic Being Towed Out of Belfast Harbor.

PARTIAL LIST OF THE SAVED.

CAPT. E. J. SMITH.

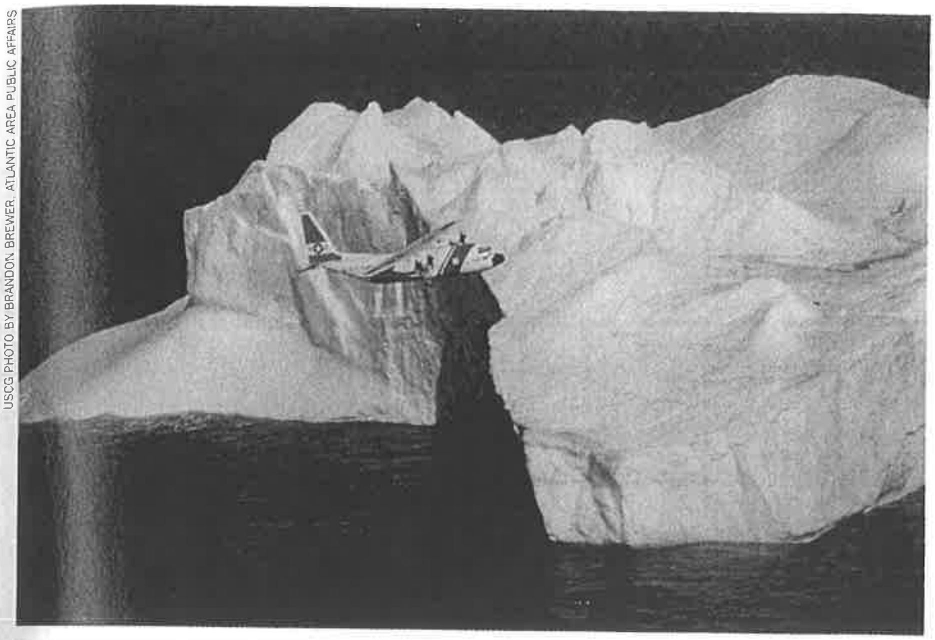
CORBIS/BETTMANN

This newspaper article reported on the disastrous maiden voyage of the Titanic. *Why was this voyage a disaster? What role did density play in the tragedy?*

AP/WIDE WORLD PHOTOS

The Titanic *now lies under 12,500 feet of water. It was made mainly from steel, which is denser than water. How did it manage to float at all?*

USCG PHOTO BY BRANDON BREWER, ATLANTIC AREA PUBLIC AFFAIRS



Icebergs float in water. What does this tell us about their density?

Why did she sink? When the *Titanic* hit the iceberg, water rushed into the ship's hull and displaced the air. The average density of the water and the steel ship was greater than the density of water. The result of this change? The *Titanic* sank to the bottom of the Atlantic. ☐

QUESTIONS

Unfortunately, life vests, or personal flotation devices (PFDs), were not enough to save the lives of many of the *Titanic's* passengers. However, they save hundreds of lives every year.

1. If you were designing a PFD, what factors would you need to take into account?
2. Draw a diagram of a PFD of your own design. Label it, explaining the role of each of its parts, and be sure to include the word "density" somewhere in your explanation.